Lecture Seventeen

Comets—The Interplanetary Nomads

Scope: Throughout history, comets appeared in the skies at seemingly random times, and they were often perceived as portents of change or catastrophe. As the mathematics of planetary orbits developed, astronomers found that some comets made periodic appearances and thus had predictable behavior. Modern studies and space missions have uncovered the details of the long tails, coma cloud, and tiny nucleus. At its heart, a comet is just a kilometer-sized icy world. Heating by the Sun and streaming through the solar wind transform it into a spectacular sight. Astronomers define two categories of comets based on the periods and orientations of their orbits. Those that cross Earth's orbit can create meteor showers, while those that have passed too close to Jupiter and the Sun have been observed to crash into them. Comets are the nomads of the solar system, with orbits that can pass near the Sun and also extend hundreds of times farther than the planets.

Outline

I. The irregular and sometimes spectacular appearances of comets have had a powerful effect on both culture and science.

- **A.** The unpredictable nature of their appearances provoked fear, and they were generally taken as portents of doom.
  - **1.** An ancient Chinese text interprets the shapes of comets' tails as indicating war or death.
  - **2.** The 1066 appearance of Halley's Comet is depicted in the Bayeux Tapestry as a bad omen for King Harold of England, who was killed later that year.
  - **3.** In 1910, when Earth passed through Halley's tail, the presence of a cyanide-like gas in its tail caused considerable media worry about the end of the world.
- **B.** The predictability of comets dates back to Edmund Halley.
  - **1.** He noted the similarities in orbit of three comets, postulated that they were the same comet, and successfully predicted its return in 1758–1759.
  - **2.** The scientific designation is 1P/Halley, where 1P indicates it is the first periodic comet.
  - **3.** Historical observations track Comet Halley's appearances back 30 orbits to 240 B.C.E.
- **C.** Predictability immediately became a scientific tool, as the late appearance of Comet Halley in 1835 was a major clue in the prediction of Neptune.

II. The structure of a comet consists of the visible head (called the coma) and tail, as well as the nucleus deep inside the coma.

- **A.** Note that our knowledge of the fine details of comets is limited to bright comets, recent comets, and comets visited by spacecraft.
- **B.** The nucleus is often described as a "dirty snowball."
  - **1.** The few observed comet nuclei have sizes of a few kilometers to tens of kilometers.
  - **2.** The surfaces are black. Ices have been removed by solar wind bombardment to leave behind encrusted carbon-rich material.
  - **3.** The surface temperature of Comet Halley when passing near Earth was 57°C (135°F), like hot asphalt baking in the Sun.
  - **4.** The gases observed indicate an interior composition of water, carbon monoxide, and carbon dioxide ices.
  - **5.** The Deep Impact mission crashed into Comet Tempel 1, revealing a crusty surface and very porous interior.
  - **6.** The plume from Tempel 1 showed materials that form at both low and high temperatures, confusing the picture of where comets form.
- **C.** Gases from the nucleus spread out to form the coma.
  - **1.** Beneath the heated surface of the nucleus, ices can sublimate to gas and shoot out as jets, carrying away dust particles as well.
  - **2.** The gas and dust form the cloud of the coma, about a million kilometers across.
  - **3.** The coma only develops within about 3 AU of the Sun.
  - **4.** Samples returned from Comet Wild 2 confirm the presence of materials that should form in different regions of the solar system.
  - **5.** The outer boundary of the coma interacts with the solar wind and can produce X-ray emissions.
- **D.** The solar wind pushes back the particles of the coma to form the tail.

1. Tails can stretch for tens of millions of kilometers and always point away from the Sun.
2. The dust particles follow orbital trajectories and produce a curved dust tail.
3. The ionized gases are carried along by the solar magnetic field to form a straight ion tail.
4. Changes in the solar wind magnetic field can produce disconnection events in which the ion tail breaks off and then re-forms.

III. Comets are classified by their orbits into short-period and long-period classes.

- **A.** The short-period comets orbit the Sun in less than 200 years.
- **B.** Their orbits are generally inside Jupiter's orbit and mostly in the plane of the ecliptic.
- **C.** The long-period comets have orbital periods greater than 200 years, with some measured in tens of thousands of years.
- **D.** Their orbit shapes are extremely elongated ellipses and are oriented at all angles.
- **E.** Most long-period comets are seen once and never seen again, while short-period comets are seen over and over until they are destroyed.

IV. Short-period comets have limited lifetimes.

- **A.** Comets lose a small percentage of their mass each passage by the Sun, giving them a rough lifetime of a few thousand orbits.
- **B.** Earth continually passes through ejected comet material, and some of it shows up in our skies as meteor showers.
- **C.** Comets can "die" by breaking apart into many fragments and fading away.
- **D.** Comets have also been observed to crash into planets and the Sun.

V. The destruction of short-period comets indicates the existence of some sort of resupply reservoir.

Suggested Readings:

Beatty, Petersen, and Chaikin, *The New Solar System*, chap. 24.

Bennett, Donahue, Schneider, and Voit, *The Cosmic Perspective*, chap. 12.

De Pater and Lissauer, *Planetary Sciences*, chap. 10.

Lewis, *Rain of Iron and Ice*.

McFadden, Weissman, and Johnson, *Encyclopedia of the Solar System*, chap. 20.

Verschuur, *Impact!*

Questions to Consider:

1. Comet Halley has a 76-year orbit, of which only about a year is spent near the Sun. For the rest of that time, what does it look like? Could we observe it?
2. Without the solar wind, would a comet have a tail?
3. Do you think the puzzling mix of materials inside a comet indicates that they started forming in one region and finished forming in another? Or, might it be that material formed in several places got mixed throughout?